§16. Microinstability of ICRF Sustained LHD Plasma

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Microinstability in ICRF sustained plasma play important role for redistribution process of absorbed RF power and provide us information from high temperature core plasma ions.

LHD has strong magnetic shear in the peripheral region of the outermost magnetic surface, then, the connection length of diverter field line become very long ($L_c \simeq 10km$ for LHD) due to the fractal processes of chaotic field lines. Furthermore, the chaotic field line region can sustain low temperature plasma, which screen the neutral atom penetrations into the magnetic surface region. CCD camera photograph of LHD coincide with the computer made chaotic field line plots in detail. LHD has no toroidal coils. Then, good confinement for reflecting particles is realized due to the circulation of banana orbits around the magnetic axis. No losscone is confirmed numerically even for transition particles whose lifetime are very long compared to the transit time ($\simeq$ machine size$/\sqrt{T/M}$). ICRF performance of LHD has investigated numerically by following equations:

$$M\frac{dV}{dt} = e\left[\begin{pmatrix} 0 \\ 0 \\ E_0 \end{pmatrix} \sin(m\phi + k_r r - \omega t) + V \times B\right]$$

$$E_0 = 5\ ,10\ ,20\ kV/m\ , \quad m = 0, 10, 40,$$

$$\frac{\omega}{2\pi} = 38.47MHz\ , \quad B_{ax} = 2.52\ ,2.75\ T\ .$$

The results show that protons are accelerated into the energy range of $1MeV$, relatively long time is necessary to reach to the maximum energy level and all escaped particles go upstream direction of the magnetic field line, and gathered at the diverter field line footprints on the diverter plate.

Theoretical model of ICRF sustained LHD plasma is constructed based on the high confinement performance for high energy particles. Then 'Runaway ion heating mode' takes place because small number of accelerated ions can absorb RF energy preferentially and confined completely. Accelerated ions are decelerated due to electron drag and body ions are sustained by relaxation process with electrons. Numerical results show that threshold ICRF power, which is determined by the plasma density, is present to sustain the LHD plasma, heating efficiency increase with ICRF power level and increase of ICRF power level take place mainly the increase of hot ion density.

Microinstability of ICRF sustained LHD plasma is analyzed through the local dispersion relation of electromagnetic wave

$$B_0(x, y, z) = (0, 0, B_0)$$

$$f_0(v) = \sum_j n_j \frac{M_j}{2\pi T_{j\perp}} \sqrt{\frac{M_j}{2\pi T_{j\parallel}}} \exp\left(-\frac{M_j(v_x^2 + v_y^2)}{2T_{j\perp}} - \frac{M_j(v_z - v_{0j})^2}{2T_{j\parallel}}\right)$$

Anisotropic temperature distribution instability is analyzed numerically under following conditions: 1) Small number of protons become hot proton, 2) $T_{h\perp} \gg T_{h\parallel}$ and 3) Plasma is relatively low β due to high magnetic field.

Numerical Computations shows that

- Low density case ($N = 1 \times 10^{19} m^{-3}$) : 1) AIC mode is a leading instability ($\omega_r \simeq 0.7\omega_{ci}$) and 2) Ion Bernstein mode and magnetosonic mode of oblique propagation become also unstable with relatively small growth rate (Fig.1).
- High density case ($N = 1 \times 10^{20} m^{-3}$): 1) Growth rate of AIC mode become small, 2) Ion Bernstein mode become stable and 3) Magnetosonic mode of oblique propagation become leading instability.

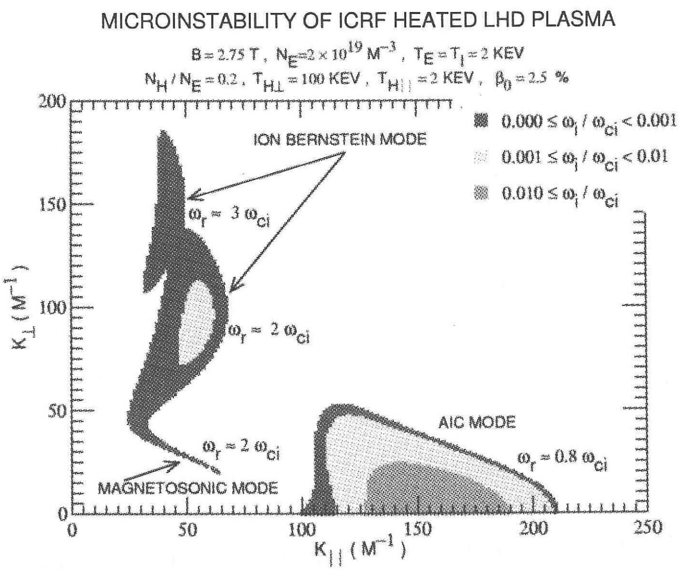

Fig.1 Microinstability in icrf sustained LHD Plasma.